

# Welcome!!

## National Risk Assessment Partnership Workshop:

### NRAP Tools for Geologic Carbon Storage Risk-Based Decision Making

Held in Conjunction with the  
Ground Water Protection Council  
2021 Annual Forum

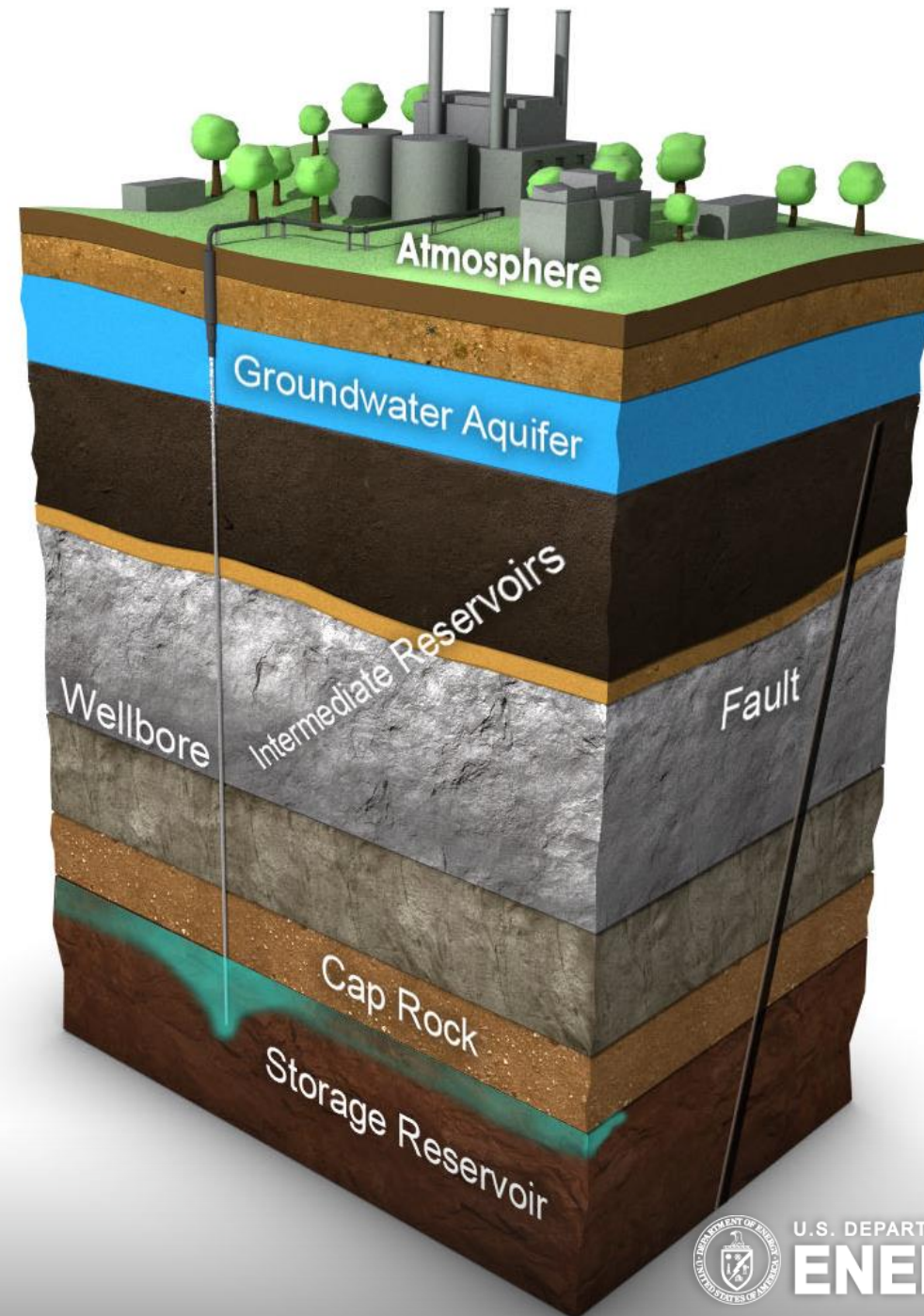


September 29, 2021

# Overview of the National Risk Assessment Partnership and NRAP Phase II Products

Robert Dilmore, NETL

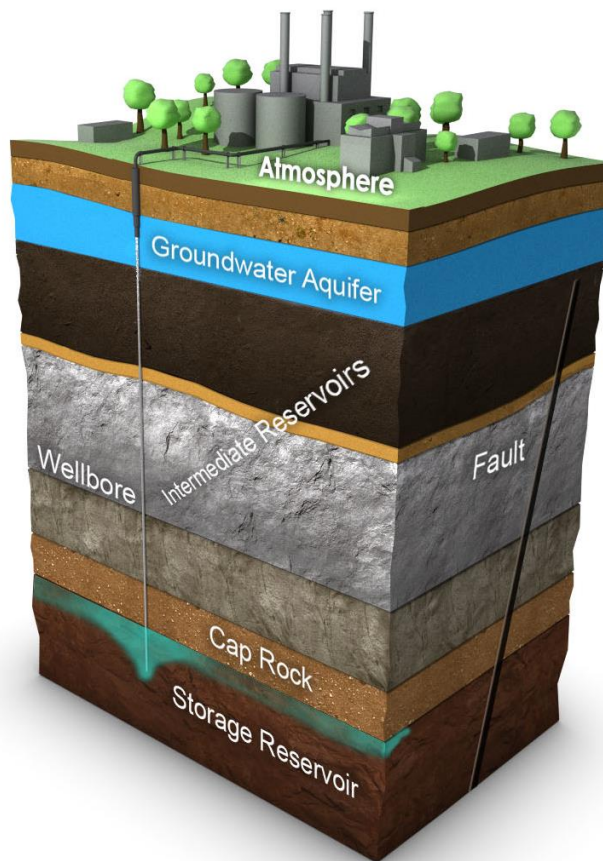
September 29, 2021



# U.S. DOE's National Risk Assessment Partnership

NRAP leverages DOE's capabilities to quantitatively assess and manage long-term environmental risks amidst significant geologic uncertainty and variability.

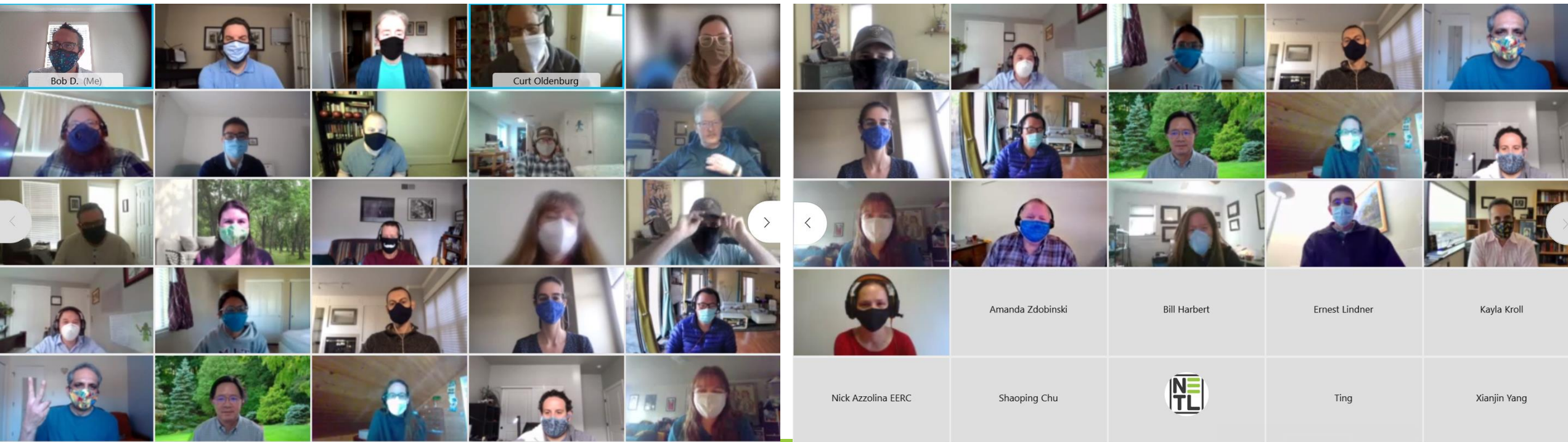
## Technical Team



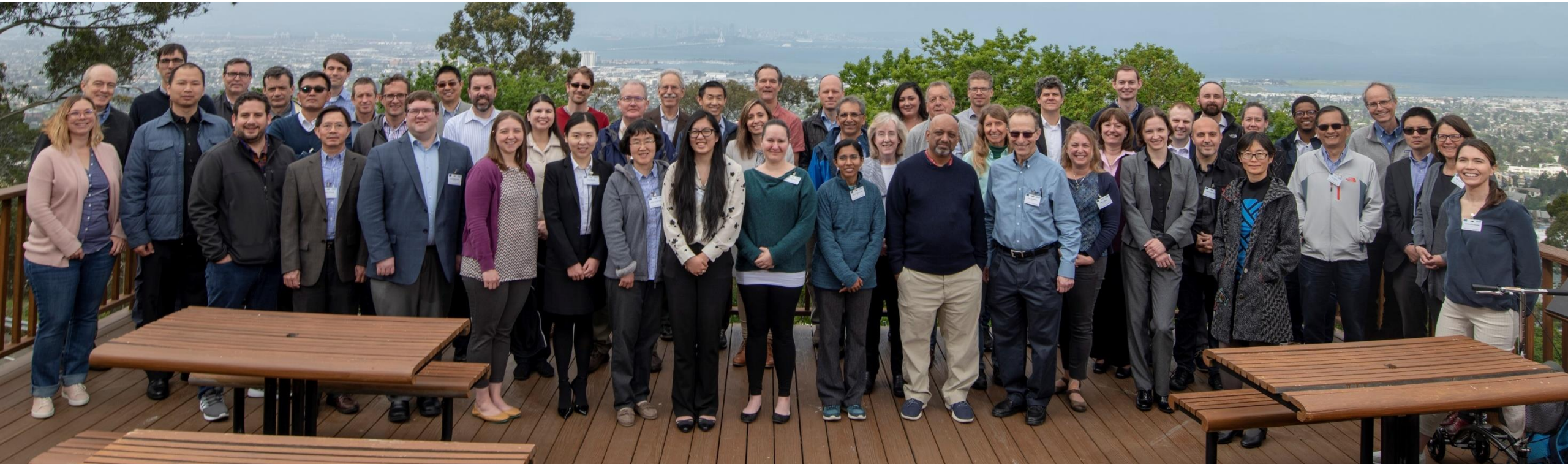
## Stakeholder Group



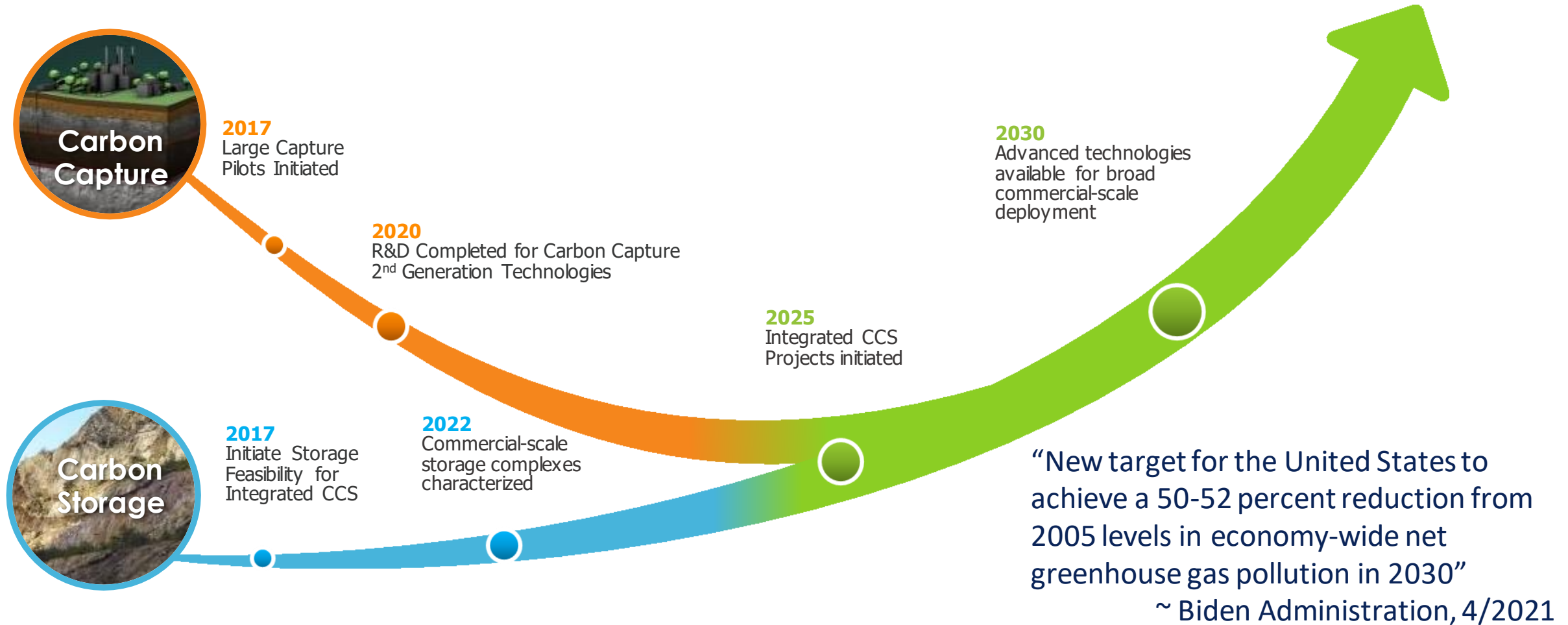
# The NRAP Team (April 2021)



# The NRAP Team (April 2019)



# Integrated R&D Approach for Commercial-Scale Deployment



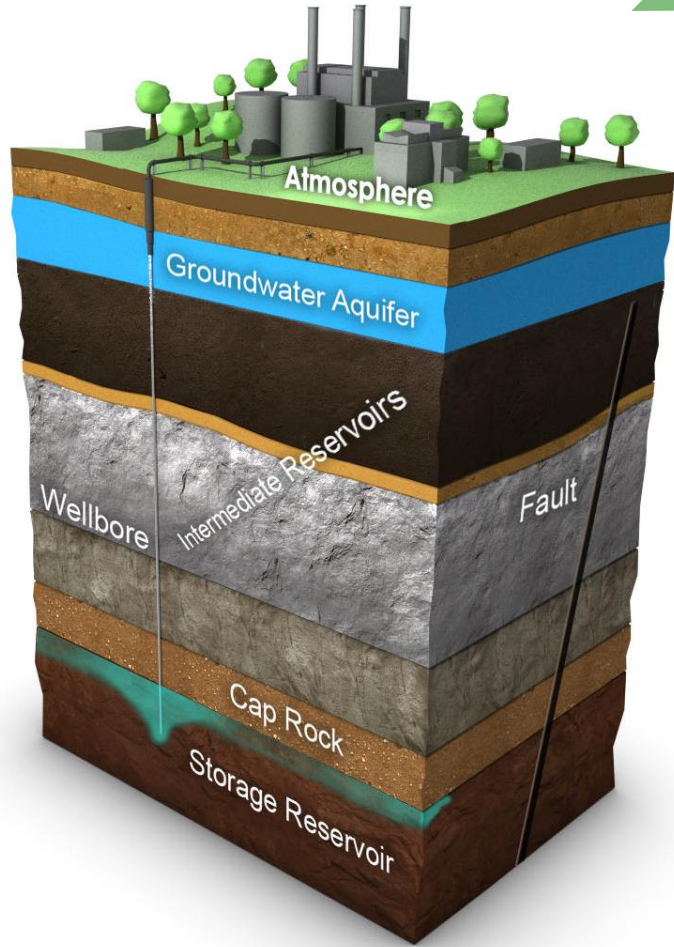
"Given the urgency and the scale on the climate change front, and the huge opportunity and need for [carbon capture, utilization and storage], we all need to do more," Turk said Tuesday. **"This is really a make-it-or-break-it opportunity and window on the CCUS front."**

David Turk,  
Deputy Secretary, US DOE

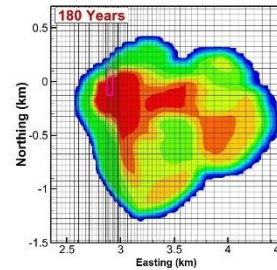
**Source:** Clark, L; Richards, H.; Anchondo, C. What Biden's 2030 climate target means for energy. E&E News April 22, 2021

# NRAP's approach for rapid prediction of whole-system risk performance

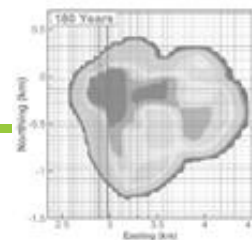
A. Divide system into discrete components



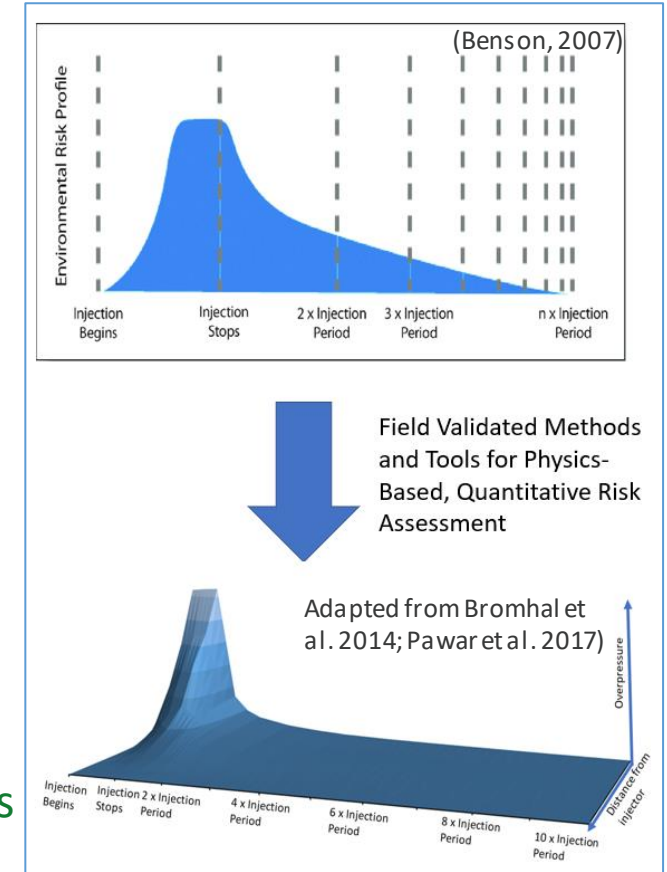
B. Develop detailed component models that are validated against lab/field data



C. Develop reduced-order models (ROMs) that rapidly reproduce component model predictions



D. Link ROMs via integrated assessment models (IAMs) to predict system performance

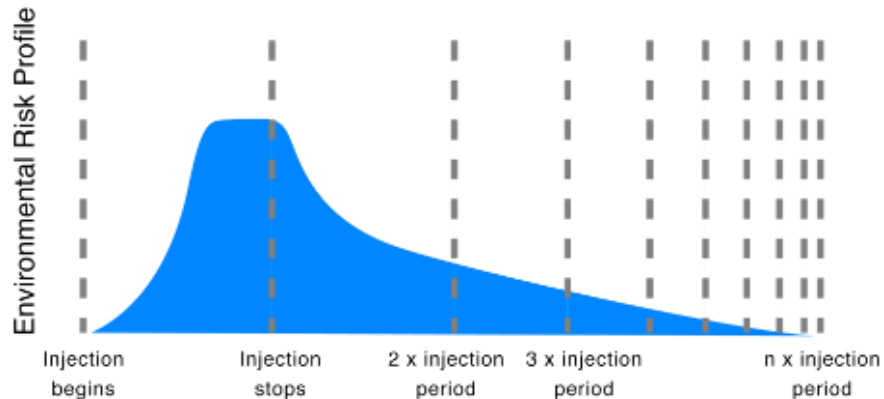


E. Exercise whole system model to explore risk performance

# NRAP Phase I (2010 – 2016)

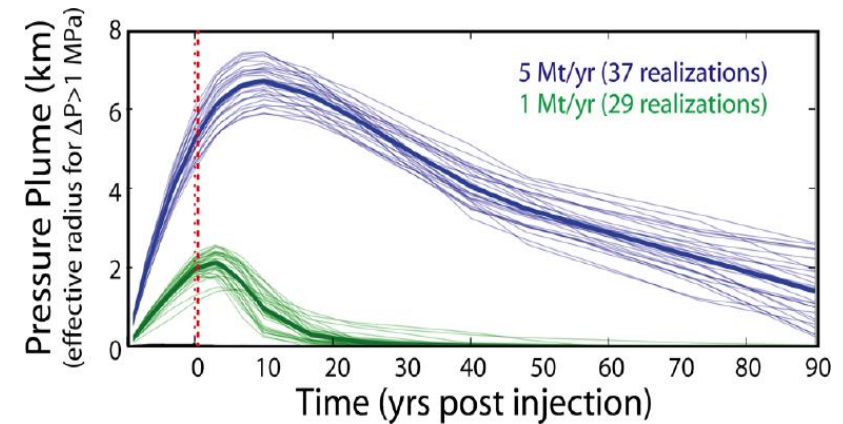
## Risk Assessment & Uncertainty Quantification

### How big might the risks be from a GCS operation?

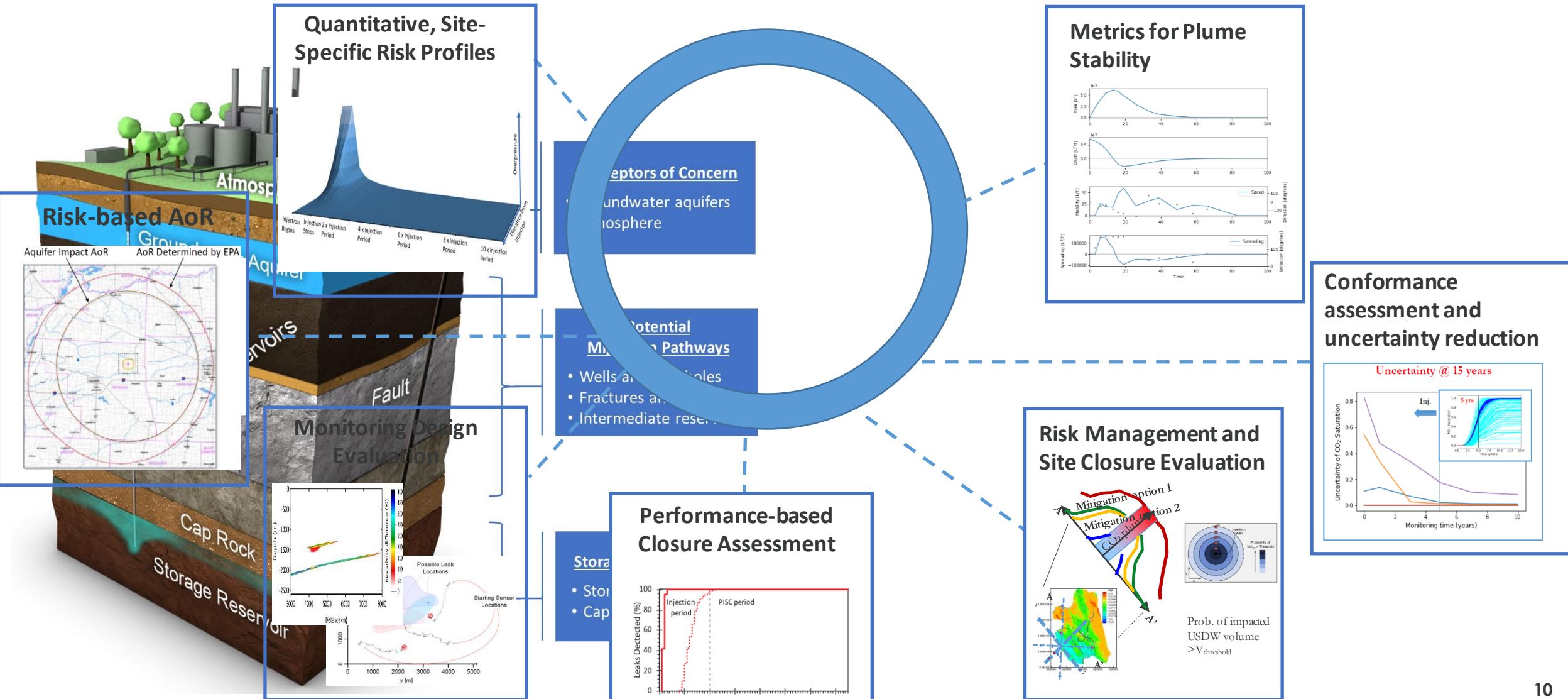


(Benson, 2007)

- Pioneered hybrid methods for quantifying complex systems (physics coupled to empirical, e.g., machine learning)
- Developed computational tools for quantifying storage post injection
- Developed foundation for strategic (risk-based) monitoring (e.g., DREAM tool; no-impact thresholds)



# Integrated Decision Support for GCS Site Risk Mgmt



# NRAP Phase II (2017–2021)

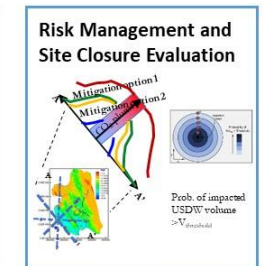
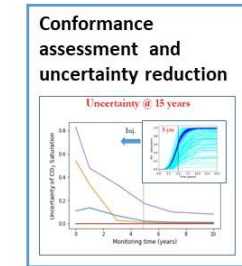
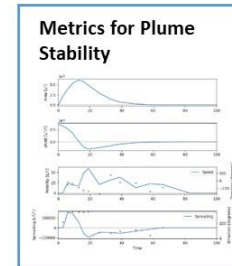
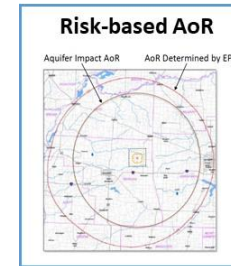
Risk Management and Uncertainty Reduction

How can a risk-based approach help inform stakeholder decision making?

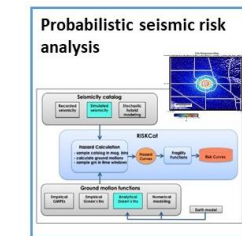
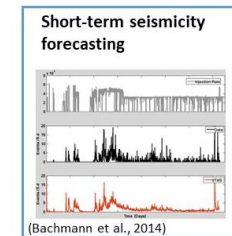
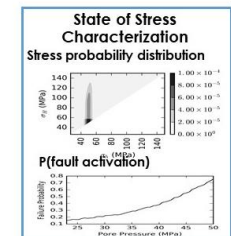
How can risks be managed at a GCS site?

## Supporting risk-based decisions at GCS sites

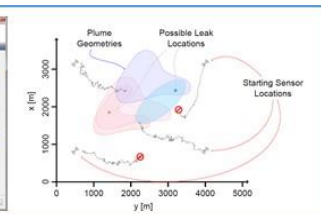
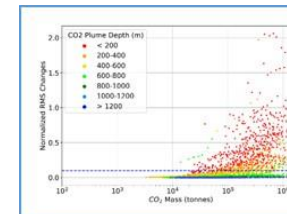
### Leakage Risk Management and Containment Assurance



### Induced Seismicity Risk Management



### Risk-Based Monitoring Network Design



# NRAP Foundational Research and Community Data

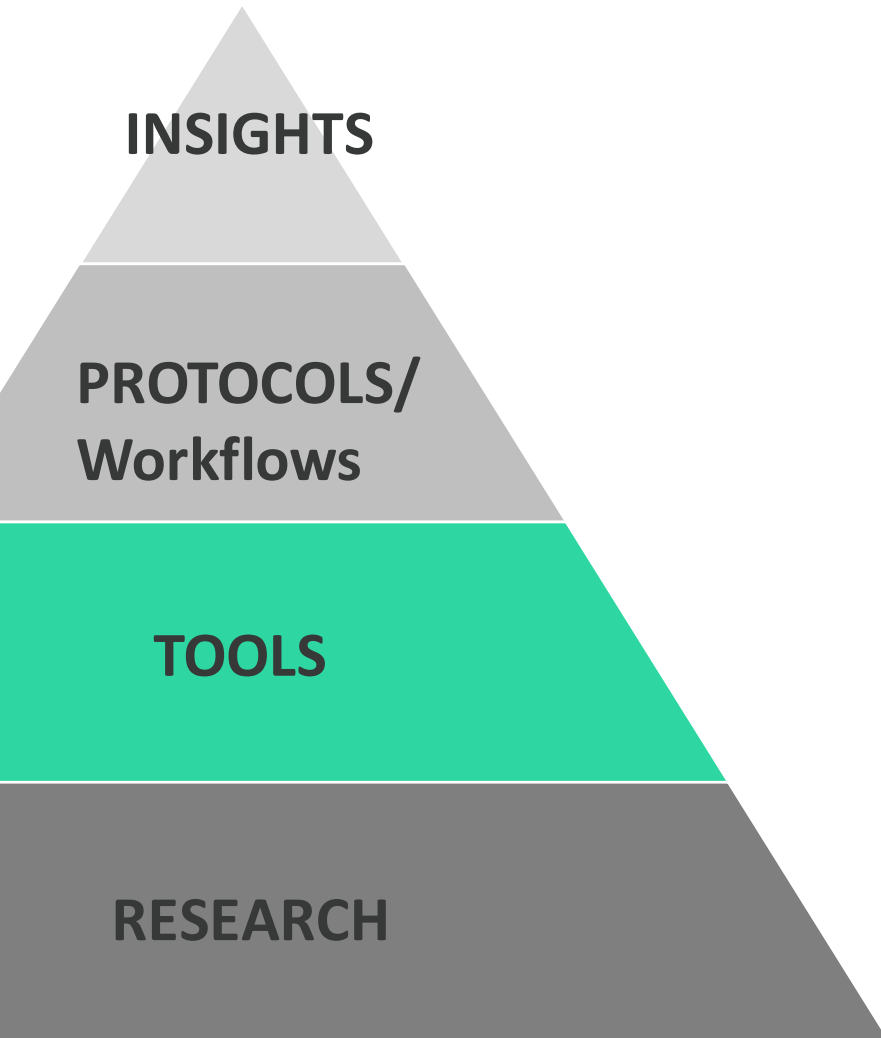


- NRAP Phase II - Virtual Special Issue *International Journal of Greenhouse Gas Control* - (September 2020)
- Community Datasets
  - Kimberlina (initial release March 2020)
  - FutureGen 2.0 (initial release October 2020)
- <https://www.osti.gov/>



~450 publications, 14,300 citations; h-index 66

12



## Leakage Risk/Containment Assurance

- NRAP Open-Source Integrated Assessment Model (NRAP-Open-IAM) - **Beta Release May 2020**

## Induced Seismicity Risk

- Short-term Seismic Forecasting Tool (STSF) – **Revision Expected 12/2021**
- State of Stress Analysis Tool (SoSAT) – **Beta release October 2018**
- Probabilistic Seismic Risk Assessment Tool (RiskCat) - **Beta release April 2020**

## Monitoring Design and Optimization

- Designs for Risk Evaluation and Management (DREAM 2.0) - **Beta Release March 2020**
- Microseismic monitoring design optimization tool – **Beta release October 2020**

# New NRAP Phase II Tools User Forum on EDX

<https://edx.netl.doe.gov/workspace/forum/nrap-tools>

Requires EDX account and permission to access NRAP tools workspace

The screenshot displays the NRAP Phase II Tools User Forum on the EDX platform. The top navigation bar includes links for EDX Home, EDX Workspaces, DOE Workspaces, and NETL Workspaces, along with a 'Create Workspace' button. The forum header shows 'NRAP Phase II Tools' with a welcome message and user statistics (Users: 191, Following: 26, Edit). A 'Data Usage: 1.737 GB' badge is visible. The main navigation bar includes Dashboard, Submissions (26), EDX Drive (73), Digital Notebooks (0), Cart (0), Forum (18), and Activity. The forum table lists various topics with their respective thread and post counts.

Topics	Last Thread	Threads	Posts
General Discussion	No recent threads.	0	0
NRAP-Open-IAM	Version and releases September 15, 2021	9	23
SOSAT	Determining probability distribution September 21, 2021	4	8
RiskCat	Can't find anything about RiskCat September 21, 2021	1	2
DREAM	No recent threads.	0	0
STSF	Not sure what unit of time to use September 21, 2021	3	7
PSMT	No recent threads.	0	0
Frequently Asked Questions	No recent threads.	0	0

# Quality Assurance

- NRAP Quality Assurance Plan
- QA for individual and coupled components
- Benchmark tests

The screenshot shows a web browser displaying the NRAP-Open-IAM Quality Assurance Documentation. The browser's address bar shows the URL: [https://nrap-iam.gitlab.io/UQ\\_example\\_setup/qaqc\\_html/index.html](https://nrap-iam.gitlab.io/UQ_example_setup/qaqc_html/index.html). The page has a dark blue sidebar on the left with navigation links: "Table of Contents", "NRAP-Open-IAM Quality Assurance Documentation Contributors", "Next topic: QA development practices", "This Page: Show Source", and "Quick search" with a search bar and a "Go" button. The main content area has a light blue header "NRAP-Open-IAM Quality Assurance Documentation". Below the header, there is a paragraph explaining that this is the documentation for the Quality Assurance (QA) for the NRAP-Open-IAM, an open-source framework for assessing risks associated with geologic carbon storage. It mentions that NRAP-Open-IAM evaluates GCS risk using an integrated assessment modeling approach, where models representing GCS components (e.g., reservoir, wellbore, shallow aquifer, atmosphere) can be linked together into a complete GCS system model. The document provides details of QA for individual components, coupled components, benchmark tests, and describes the process whereby NRAP-Open-IAM maintains QA during development. Below this paragraph, there is a section titled "NRAP-Open-IAM Quality Assurance Plan." with a bulleted list: "QA development practices", "System model components", "Benchmark Tests", and "Test Suite". Further down, there is a section titled "Contributors" with a list of names and their affiliations: Dylan Harp, Los Alamos National Laboratory; Veronika Vasylykivska, National Energy Technology Laboratory; Diana Bacon, Pacific Northwest National Laboratory; Yingqi Zhang, Lawrence Berkeley National Laboratory; Kayyum Mansoor, Lawrence Livermore National Laboratory; Jaisree Iyer, Lawrence Livermore National Laboratory; and Ernest Lindner, National Energy Technology Laboratory. At the bottom of the contributors list, there are links to "Index", "Module Index", and "Search Page".

dev documentation » NRAP-Open-IAM Quality Assurance Documentation

## NRAP-Open-IAM Quality Assurance Documentation

This is the documentation of the Quality Assurance (QA) for the NRAP-Open-IAM. The NRAP-Open-IAM is an open-source framework for assessing risks associated with geologic carbon storage. NRAP-Open-IAM evaluates GCS risk using an integrated assessment modeling approach, where models representing GCS components (e.g., reservoir, wellbore, shallow aquifer, atmosphere) can be linked together into a complete GCS system model. This document provides details of QA for individual components, coupled components, benchmark tests, and describes the process whereby NRAP-Open-IAM maintains QA during development.

NRAP-Open-IAM Quality Assurance Plan.

- QA development practices
- System model components
- Benchmark Tests
- Test Suite

## Contributors

Dylan Harp, Los Alamos National Laboratory

Veronika Vasylykivska, National Energy Technology Laboratory

Diana Bacon, Pacific Northwest National Laboratory

Yingqi Zhang, Lawrence Berkeley National Laboratory

Kayyum Mansoor, Lawrence Livermore National Laboratory

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Ernest Lindner, National Energy Technology Laboratory

- Index
- Module Index
- Search Page

# NRAP Application Catalog on EDX

N. Huerta, D. Appriou, D. Bacon (PNNL); P. Morkner (NETL); T. Jones, A. Barkhurst (MATRIC)

- Summary of 16 studies including
  - Prototype tool testing/method development
  - Site characterization
  - Analog studies
- Link to relevant publications



NRAP released a set of open-source computational tools designed to help evaluate the performance of geological carbon storage sites and to assess risks across a project's life cycle. The NRAP tools enable stakeholders and operators to rapidly explore the behavior of the storage complex and to evaluate containment effectiveness and quantify leakage risk, assess geomechanical risks and manage induced seismicity, and develop risk-based monitoring strategy for uncertainty reduction.

[More...](#)



# Validating NRAP tools and approaches

## Prototype testing / method development

1. NRAP-IAM-CS Used to Estimate A oR and Impact of Legacy Well Leakage
2. Application of WLAT and DREAM for Risk Based Monitoring Design
3. Coupling of NRAP-Open-IAM and DREAM for Risk-based Monitoring Design and PISC Period Determination at the FutureGen 2.0 site
4. Probabilistic Risk-based A oR Determination at FutureGen 2.0 Site
5. Application of NRAP-Open-IAM to the Kimberlina Site
6. Application of SOSAT for State-of-stress Analysis at the FutureGen 2.0 Site
7. Evaluating Probability of Containment Effectiveness at FutureGen 2.0 Site

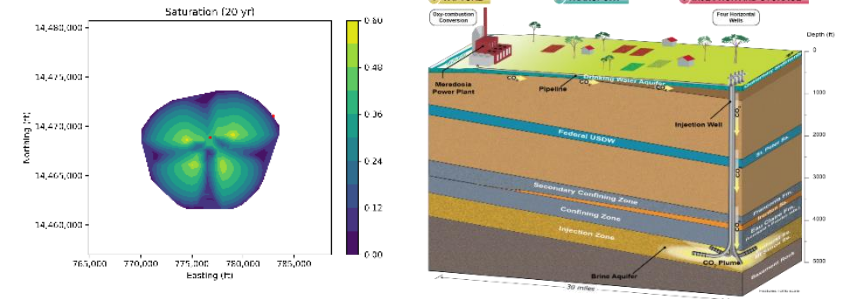
## Analog studies

1. Oklahoma Wastewater Injection as Analog for CO<sub>2</sub> Sequestration
2. Statistical Analysis of the Induced Basel 2006 Earthquake Sequence

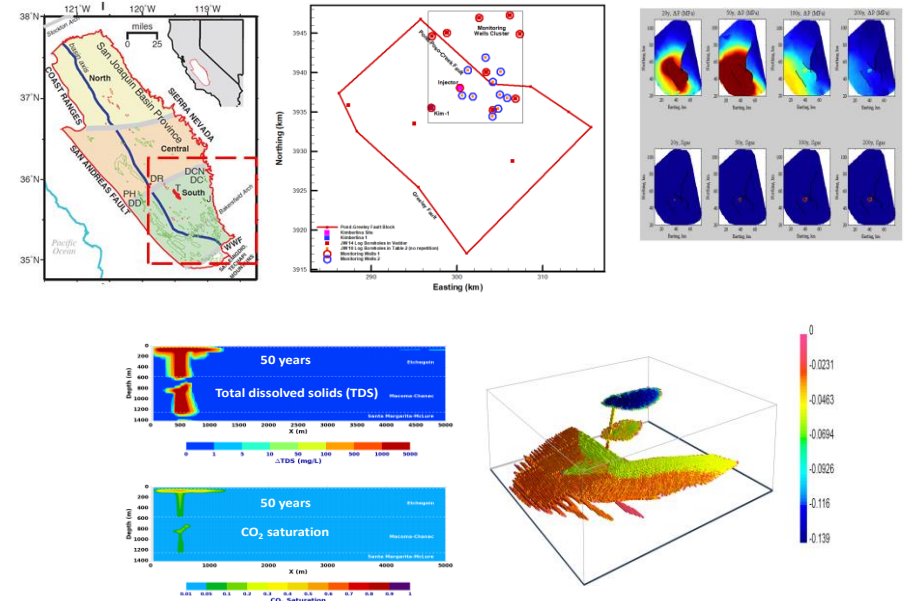
## Preliminary site-characterization

1. Application of NRAP-IAM-CS for Preliminary Risk Assessment for GCS Candidate Site Selection
2. Application of NRAP-IAM-CS at Rock Springs Uplift Site
3. Application of NRAP-IAM-CS to Illinois East Sub-Basin CarbonSAFE
4. Application of the Aquifer Impact Model to the Decatur Site
5. State of Stress Analysis of the Farnsworth Site
6. Application of NRAP-Open-IAM to Illinois Christian (Macon) County CarbonSAFE
7. Application of NRAP-Open-IAM and SOSAT at Existing Oil Fields in IMCSC CarbonSAFE

## Retrospective risk assessment at FutureGen 2.0 site



## Kimberlina, San Joaquin Basin, CA



# Recommended Practices for Risk Management

INSIGHTS

PROTOCOLS/  
Workflows

TOOLS

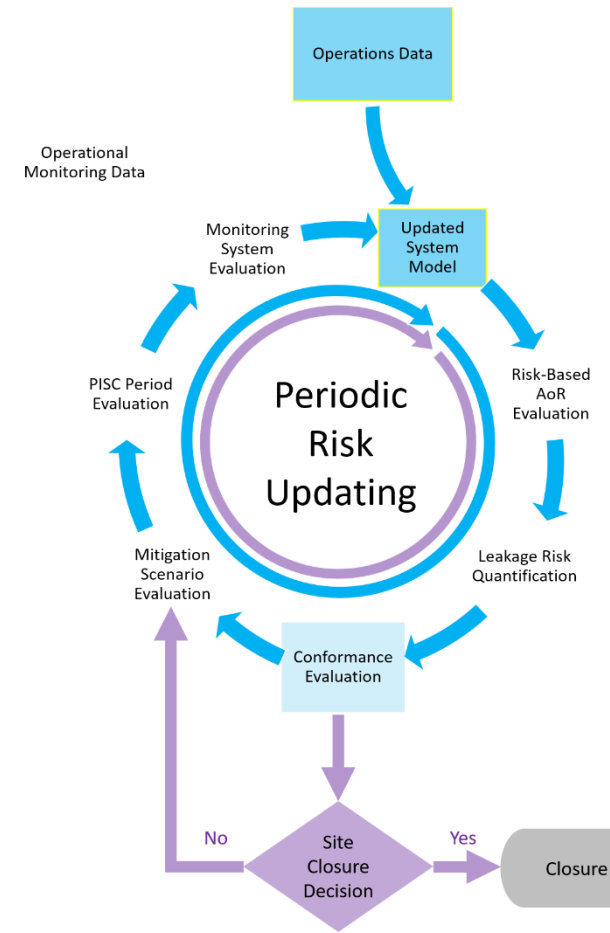
RESEARCH

## Induced Seismicity Risk Management

- Step 1** Perform a preliminary screening evaluation.
- Step 2** Implement an outreach and communication program.
- Step 3** Review and select criteria for ground vibration and noise.
- Step 4** Establish seismic monitoring.
- Step 5** Quantify the hazard from natural and induced seismic events.
- Step 6** Characterize the risk of induced seismic events.
- Step 7** Develop risk-based mitigation plan.

Drafts Released March 8, 2021  
Feedback still being accepted  
Comments to: [NRAP@netl.doe.gov](mailto:NRAP@netl.doe.gov)

## Leakage Risk Management and Containment Assurance



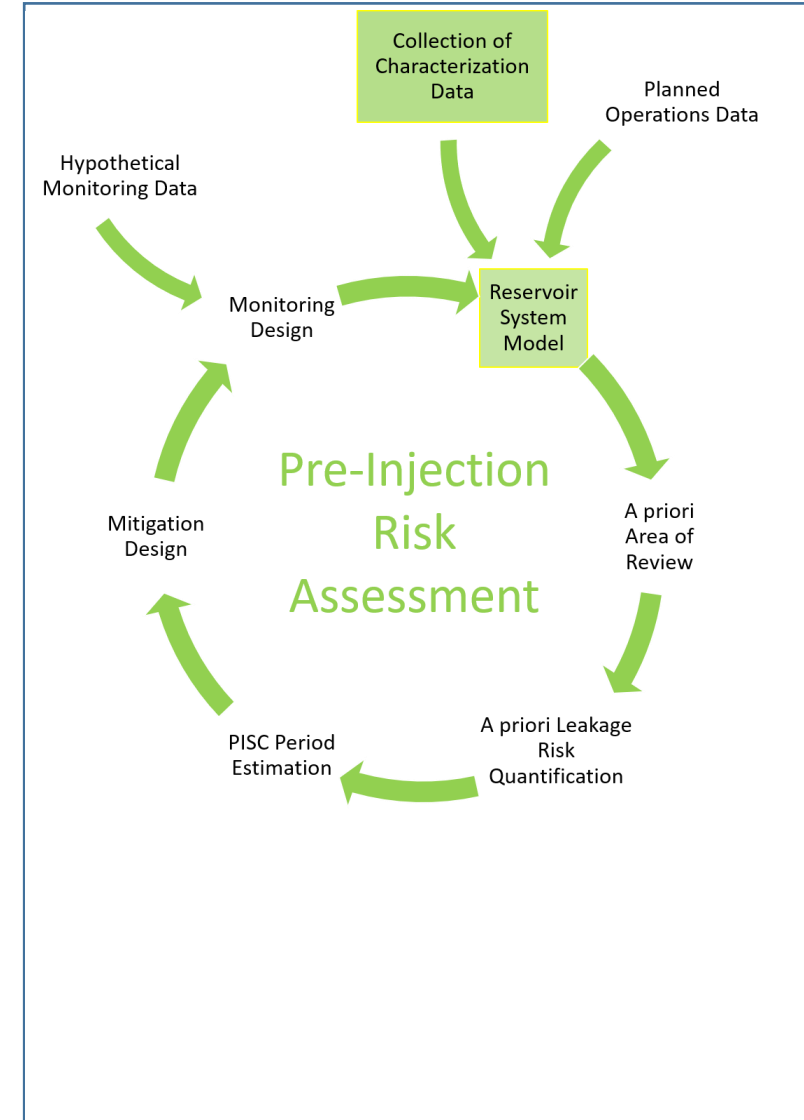
# Task 6: Addressing critical risk-related questions

## Recommended Practices Containment Assurance and Leakage Risk Management (Thomas et al., **DRAFT**)

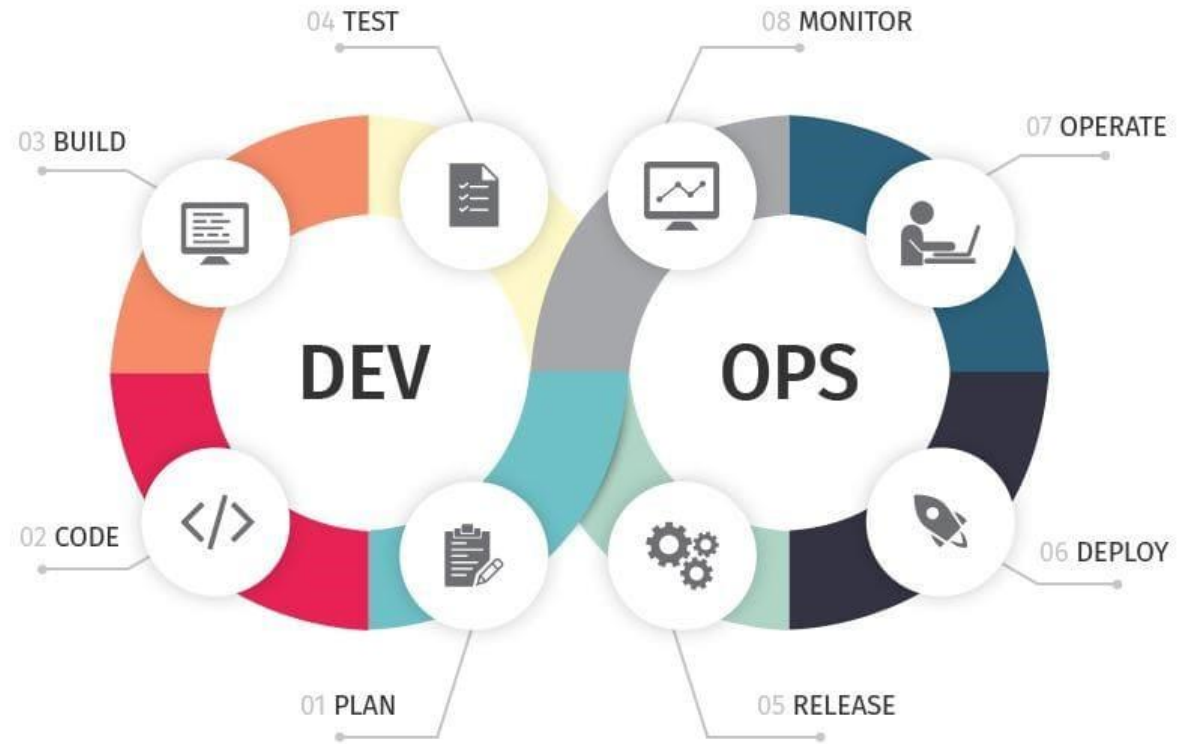
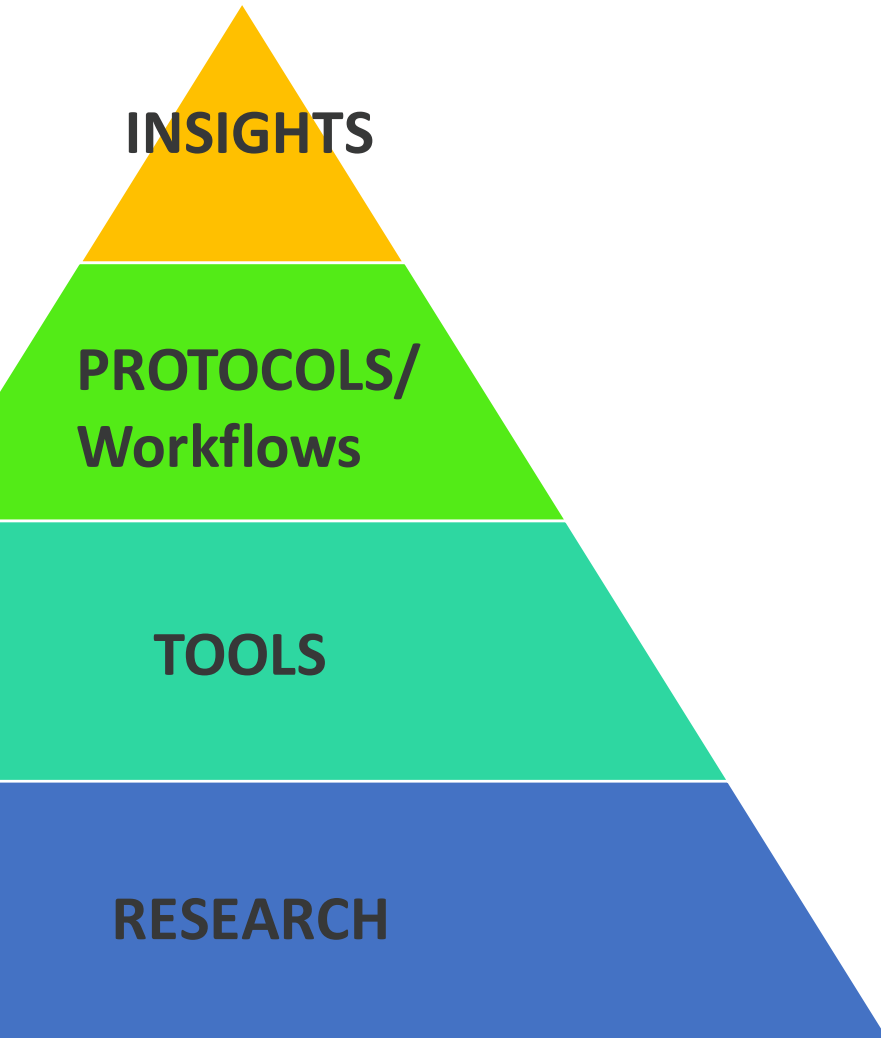
- Planning and Execution of Risk-based GCS Site Characterization
- Characterization of State of Stress and Geomechanical Conditions
- Developing a Risk-based AOR
- Risk-based Strategic Monitoring
- Assessing GCS System Conformance
- Evaluating Mitigation Scenarios to Inform Risk Management Decisions (under development)
- Defining a Risk-based Period of Post-injection Site Care in Support of Site-Closure Decision-making

**Draft Released March 8, 2021**  
**Feedback still being accepted**  
**Comments to: [NRAP@netl.doe.gov](mailto:NRAP@netl.doe.gov)**

<https://edx.netl.doe.gov/dataset/draft-nrap-recommended-practices-for-containment-assurance-and-leakage-risk-quantification>



# NRAP Products and Stakeholder Engagement



**DEV-OPS Image SOURCE:** [https://res.cloudinary.com/practicaldev/image/fetch/s--dbI8WY9--/c\\_limit%2Cf\\_auto%2Cfl\\_progressive%2Cq\\_auto%2Cw\\_880/http://aisaac.io/content/images/2018/11/DevOps.jpg](https://res.cloudinary.com/practicaldev/image/fetch/s--dbI8WY9--/c_limit%2Cf_auto%2Cfl_progressive%2Cq_auto%2Cw_880/http://aisaac.io/content/images/2018/11/DevOps.jpg)

# Engaging with Key Stakeholders

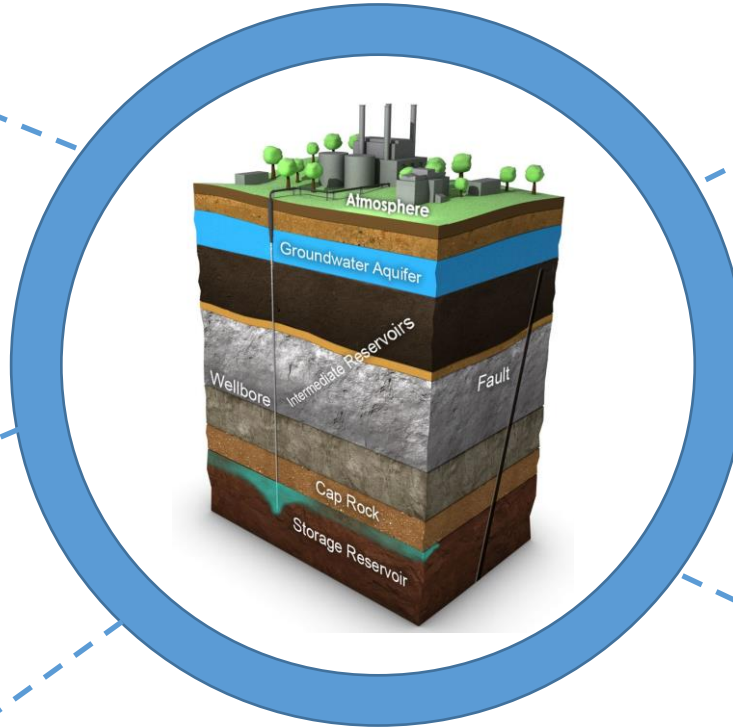
## DOE CarbonSAFE



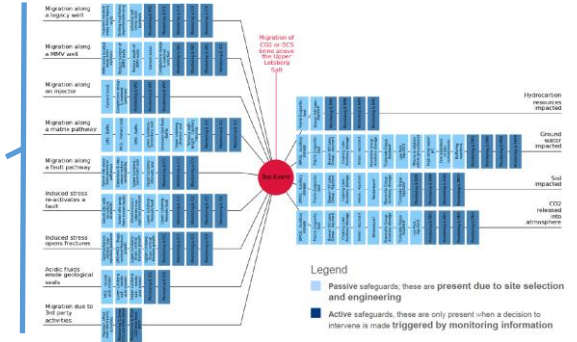
## DOE-FE Regional Initiatives



## DOE-FE SMART Initiative



## Industry Best Practices

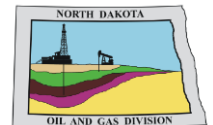


Bourne et al., 2014

## International CCUS RD&D Community



## Regulatory Context



# SMART Initiative

Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications



**Real-Time Visualization**  
*"CT" for the Subsurface*



**Rapid Prediction**  
*Virtual Learning*



**Real-Time Forecasting**  
*"Advanced Control Room"*

Transforming decisions through **clear vision** of the present and future subsurface.

## Technical Team

Carnegie  
Mellon  
University

Los Alamos  
NATIONAL LABORATORY



NATIONAL  
ENERGY  
TECHNOLOGY  
LABORATORY

BATTELLE

EERC  
UNIVERSITY OF  
NORTH DAKOTA

FACT

Lawrence Livermore  
National Laboratory

COLORADO SCHOOL OF  
MINES

OAK RIDGE  
National Laboratory

PennState

THE UNIVERSITY  
OF UTAH®

Pacific Northwest  
NATIONAL LABORATORY

BUREAU OF  
ECONOMIC  
GEOLOGY



Sandia  
National  
Laboratories

BERKELEY LAB

ILLINOIS

# Thank you!

Comments and Questions:

[Robert.Dilmore@netl.doe.gov](mailto:Robert.Dilmore@netl.doe.gov)

[NRAP@NETL.doe.gov](mailto:NRAP@NETL.doe.gov)

NRAP Website: <https://edx.netl.doe.gov/nrap/>

Sign up for NETL EDX: <https://edx.netl.doe.gov/user/register>

